BATTERY WITH VIBRATION-RESISTANT JOINT BETWEEN POSITIVE ELECTRODE AND CURRENT CARRYING STRAP

FIELD OF THE INVENTION

[0001] The invention relates generally to batteries, and more particularly to lead-acid batteries.

BACKGROUND OF THE INVENTION

[0002] A typical battery includes one or more electrochemical cells which are electrically connected within the battery and provide the source of electrical power for the battery. These cells generally comprise four basic components: a positive electrode (anode on charge and cathode on discharge) that receives electrons from an external circuit as the cell is discharged; a negative electrode (cathode on charge and anode on discharge) that donates electrons to the external circuit as the cell is discharged; an electrolyte (often in a solution or paste) which provides a mechanism for electrical charge to flow between the positive and negative electrodes; and one or more separators which electrically isolate the positive and negative electrodes. This configuration enables the cell to generate electric power because of the electrochemical relationship of these components. Once the current is generated, it is typically carried from the positive electrode plates through a current carrier to a terminal, from which it is conveyed to the external circuit and back into the battery through a terminal connected with the negative electrode plates (typically through another current carrier).

[0003] Lead-acid batteries are popular when rechargeability is desired. These batteries are particularly desirable for rechargeable use due to their high tolerance for abuse and relatively low manufacturing cost, particularly when battery weight is not a great concern. As a result, lead-acid batteries are often employed to power automobiles and other vehicles, as these environments can be quite harsh and present varied forms of maltreatment. Lead acid batteries are also often used in backup systems that provide power when an electrical power grid fails.

[0004] Most lead-acid batteries generally rely on the same fundamental electrochemical reaction to produce power and typically employ the same active materials. The electrochemical reaction is shown below:

CATHODE
$PbO_2 + SO_4^{-2} + 4H^+ + 2e^- \rightarrow PbSO_4 + 2H_2O$
ANODE
$Pb + SO_4^{-2} \rightarrow PbSO_4 + 2e^-$

[0005] At the anode, metallic lead reacts with sulfate ion (SO_4^{2-}) and is converted to lead sulfate ($PbSO_4$). At the cathode, lead dioxide (PbO_2) reacts with sulfate ion (SO_4^{2-}) and is also converted to lead sulfate. Electrons are donated by the anode and travel through the external circuit to be received by the cathode.

[0006] In practice, a typical lead-acid battery includes multiple overlying anode and cathode layers. Most often, these are arranged in one of two configurations: stacked plates or spirally wound elongate strips. In either instance, the anode and cathode layers are separated from each other by separator layers formed of an electrically-insulative material (typically a glass fiber mat or the like). A dilute sulfuric acid solution is typically used as the electrolyte to provide the sulfate ion.

[0007] The stacked plate variety of lead-acid battery ordinarily includes multiple anode and cathode plates alternately sequenced in a stack separated by separator layers. In other words, the typical arrangement comprises a cathode plate, a separator layer, an anode plate, another separator layer, a second cathode plate, and so on. Some lead-acid battery cells include as many as **29** cathode and anode plates stacked in this fashion.

[0008] To harness the energy created by the electrochemical reactions occurring with the plates, the cathode plates are connected to each other in parallel, and the anode plates are separately connected to each other in parallel. One common technique for connecting the plates is to include a projecting tab from one edge of each plate. The tabs are located in the same position on each cathode plate so that they align when the plates are stacked. The tabs are attached to a conductive connecting strap that is, in turn, connected to the battery terminal. Similar aligned tabs project from the anode plates and are connected by a connecting strap, but the tabs are located in a different position on the anode plates so as to avoid interfering with the cathode strap. One example of this configuration is described in U.S. Pat. No. 4,383,011 to McClelland et al.

[0009] One difficulty that can be experienced by lead-acid batteries having this design regards the vibration resistance and durability of the batteries. As discussed above, because lead-acid batteries are typically hardy, they are often used in harsh environments. As such, they are subjected to rigorous testing, particularly for shock, bump, impact and vibration resistance (for an exemplary test, see VG96924-2, BS6290 part 4, IEC). In some instances, fractures occur at the joints between the tabs of the positive electrode plates and the connecting strap. This area of the positive electrode plate can become brittle due to oxidation (i.e. the formation of PbO_2) that takes place on the surface of the tabs to protect the underlying bulk metallic lead (Pb). The PbO_2 layer is relatively brittle, and can crack under the shearing loads imparted during vibration tests. These cracks then expose the bulk metallic lead underneath, which then oxidizes. This pattern of oxidation followed by cracking repeats until the tabs fracture completely from the plate.

SUMMARY OF THE INVENTION

[0010] The invention is directed to cells and batteries and methods of their manufacture that can assist fracture resistance at the joint between the positive electrode plate tabs and the connecting strap during vibration and other rigorous mechanical tests. As a first aspect of the invention, a method of manufacturing a battery comprises as an initial step providing a cell for a battery having alternating positive and negative electrode plates, wherein each of the electrode plates is separated by an electrically insulative separator layer, and the positive and negative electrode plates are in overlying relationship. Each of the positive electrode plates includes a projecting tab extending from an adjacent upper